Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Expanding Access to Broadband and Encouraging Innovation through Establishment of an Air-Ground Mobile Broadband Secondary Service for Passengers Aboard Aircraft in the 14.0-14.5 GHz Band	GN Docket No. 13-114 RM-11640

REPLY COMMENTS OF QUALCOMM INCORPORATED

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SUMMARY

The Air-Ground Mobile Broadband Service NPRM received strong support from a wide variety of stakeholders, including major U.S. airlines, equipment manufacturers, service providers, and key industry trade associations, such as CTIA – The Wireless Association, the Information Technology Industry Council ("ITI"), the Telecommunications Industry Association ("TIA"), and the National Association of Broadcasters ("NAB"). All of these commenters agree that the Commission should promptly establish the proposed service in the 14.0 - 14.5 GHz band so that airplane passengers can enjoy high-speed, high-capacity Internet connectivity while flying above the continental United States.

Each of these commenting parties "supports the improvement of broadband connectivity aboard aircraft, and agrees that the proposal should increase competition and service quality and provide travelers with a greater ability to communicate, obtain information and stream entertainment content." NAB Comments at 1; *see also* Comments of American Airlines, Delta Airlines, Facebook, Gogo Inc., Honeywell, and United Airlines. They recognize that, as the Commission itself tentatively concluded in the NPRM, that such a multi-gigabit-per-second service can successfully operate on a secondary basis and share spectrum with incumbent primary Fixed Satellite Service ("FSS") operations and other users of the 14.0 GHz band.

There is also a consensus that the proposed service is needed now. Soaring numbers of U.S. air travelers are carrying smartphones, tablets, e-readers, and laptops on board aircraft, and they fully expect to use those devices in the air with the same level of broadband connectivity that they have on the ground. As Facebook itself explains, "Millions of Facebook users would welcome the new service and take full advantage of mobile broadband connectivity in the sky." There is no question that the FCC will bring tremendous benefits to consumers by authorizing

this new service, which will be offered at a very reasonable cost using innovative terrestrial-based technology.

The record of this proceeding now contains strong support for the Commission's proposal to establish the proposed new service. As Qualcomm explained in its opening Comments, we support the FCC's proposed regulatory framework and technical operating rules for the Air-Ground Mobile Broadband Service and strongly encourage the Commission to issue a Report and Order establishing the new service and conduct an auction as soon as possible thereafter, so the traveling public can experience the high-quality, high-capacity in-flight broadband experience they demand.

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QUALCOMM Incorporated ("Qualcomm") is pleased to file these reply comments with the Commission in strong support of the above-captioned Notice of Proposed Rulemaking.[1] The NPRM proposes to establish a new Air-Ground Mobile Broadband Service that will extend the same level of broadband access that users currently enjoy everywhere on the ground to the aircraft cabin. The overwhelming majority of commenting parties recognize that the proposed Air-Ground Mobile Broadband Service can operate on a secondary licensed basis in the 14.0 - 14.5 GHz band without causing interference to primary satellite operations and other incumbent users of this band and without suffering any interference.[2] Each of these parties encourages the

1 *See Expanding Access to Broadband and Encouraging Innovation through Establishment of an Air-Ground Mobile Broadband Secondary Service for Passengers Aboard Aircraft in the 14.0-14.5 GHz Band*, Notice of Proposed Rulemaking, GN Docket No. 13-114, RM-11640, FCC 13-66, 28 FCC Rcd 6765 (2013) ("NPRM").

2 *See* Comments of American Airlines, CTIA – The Wireless Association, Delta Airlines; Facebook, Gogo Inc., Honeywell Inc., Information Technology Industry Council ("ITI"), National Association of Broadcasters ("NAB"), Telecommunications Industry Association ("TIA"), and United Airlines. *See also* ViaSat Comments at 2; Echostar Comments at 1.

Commission to promptly establish the proposed service in accordance with the proposals in the NPRM so that U.S. air travelers can have high-speed, high-capacity in-flight broadband access.[3]

As the Commission itself explains in the NPRM, "broadband aboard aircraft will lead to improved connectivity for business and leisure travelers alike. Business travelers will have a greater ability to message, research and download information, and send finished products. Leisure travelers will have greater options to use broadband to communicate with friends and family members, use social media, play games, and research their destinations or other areas of interest."[4] The new service also will allow air travelers to stream videos, movies, television programming, radio stations, and any other content of their choice. The record demonstrates overwhelming support for the FCC's proposal to adopt rules to enable this exciting new service.

DISCUSSION

I. Major U.S. Airlines, Equipment Manufacturers, And Application & Service Providers Confirm That U.S. Air Travelers Want In-Flight Broadband Connectivity

American air travelers are carrying on board aircraft smartphones, tablets, and laptops, and desperately want to continue using these devices while they are flying above the Continental U.S. ("CONUS"). Indeed, as Acting Chairwoman Clyburn explained: "[B]roadband is no longer a luxury, it is a necessity."[5]

Mobile broadband usage continues to increase at exponential rates because the advanced capabilities and applications supported by today's mobile devices are providing exponentially increasing value to consumers. American Airlines explains that "U.S. air travelers expect

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3 *See id.*

4 NPRM at ¶ 17.

5 Prepared Remarks of FCC Acting Chairwoman Mignon L. Clyburn, M-Enabling Summit, Arlington, VA (June 6, 2013) *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0607/DOC-321475A1.pdf.

anywhere/anytime broadband access" because they need to continue using their mobile devices while in-flight.[6] Also, "Delta's customers have come to expect access to the Internet on every domestic flight, and Delta means to meet those expectations."[7] In this same vein, United Airlines explains that it "is committed to providing a progressively richer in-flight experience that meets and exceeds passenger expectations, and it appreciates the Commission's efforts to make more spectrum available for in-flight broadband."[8]

Honeywell, the provider of avionics used to support U.S. airline use of Aircell's GoGo air-ground service is "particularly pleased that the FCC has proposed this new air-ground broadband service on-board aircraft because it can provide the necessary level of connectivity."[9] And, Facebook is "convinced that these passengers would take advantage of the high-speed air-ground network proposed in the NPRM to visit Facebook while they are inflight. … Millions of Facebook users would welcome the new service and take full advantage of mobile broadband connectivity in the sky."[10]

A. Soaring Consumer Use Of Mobile Broadband-Enabled Devices Is Fuelling The Need For A High-Quality In-Flight Broadband Experience

As United Airlines states, "the expansion of in-flight wireless Internet connectivity is important to the traveling public.[11] This exponential growth in consumer use of data-hungry smartphone and tablet mobile apps is driving growth in the mobile broadband ecosystem. Users

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6 *See* American Airlines Comments at 1.

7 *See* Delta Airlines Comments at 1.

8 *See* American Airlines Comments at 1.

9 *See* Honeywell Comments at 1.

10 *See* Facebook Comments at 1-2.

11 *See* United Airlines Comments at 8.

not only are using their devices more often, but the apps with which they regularly interact are becoming increasingly sophisticated with greater data needs.

Facebook's "mission is to make the world more open and connected by giving people a platform to connect and share with family and friends. Allowing people to remain connected while in-flight is an important element of this mission."[12] Indeed, as the social networking behemoth knows well, with each passing day more and more consumers are adopting a connected lifestyle in which anywhere/anytime mobile broadband connectivity is expected — including when they are flying in a plane. The ability of travelers to use devices while seated on an airplane in a quiet environment is likely to result in an increase in mobile broadband data usage when compared to such usage on the ground.

Airlines are actively promoting the opportunity to "take your business above the ground."[13] Thus, it is not surprising that U.S. airlines are looking for "additional capacity alternatives to satellite based systems that suffer from high latency and high costs.[14] United Airlines explains that the new service would allow the airline "and its partners to develop more advanced onboard enterprise solutions capable of delivering customizable and differentiated content to United's passengers, in addition to meeting broader connectivity needs."[15] The market for in-flight broadband services is perceived as an attractive business opportunity and one that remains underserved.[16]

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12 *See* Facebook Comments at 1.

13 JetBlue is promoting this "stay connected inflight opportunity." *See* http://www.jetblue.com/flying-on-jetblue/wifi/.

14 Delta Airlines Comments at 1-2.

15 United Airlines Comments at 4.

16 Gogo noted that the number of scheduled passengers on commercial aircraft worldwide is expected to grow to 3.1 billion in 2013 and there is a "significant opportunity…to expand into this underserved market. Gogo, Inc., Prospectus, SEC Form 424B4 at 3 (filed June 24, 2013).

B. <u>More Broadband Spectrum Is Needed To Satisfy The Needs Of Air Travelers</u>

Given that U.S. commercial airlines expect demand for in-flight broadband connectivity to continue to surge in the coming years, "substantially more spectrum will be needed."[17] Authorizing the proposed service offers "tremendous promise for passengers and airlines" such as "increased options and competition for in-flight broadband service, lower prices for consumers and airlines that serve the public, and improved in-flight broadband quality."[18] There is no question that the creation of the Air-Ground Mobile Broadband Service will "help meet consumer demand by offering airline passengers access to better in-flight broadband" and "enable business and leisure travelers aboard aircraft in the United States to be more productive and have more choices in entertainment, communications, and social media" while potentially lowering prices.[19]

According to the Gartner research firm, "More than two billion portable electronic devices will be sold this year" and "[a]ir travelers own a disproportionately large share of these devices, particularly smartphones and tablets, whose use is growing at the fastest rate."[20] Indeed, as CTIA – The Wireless Association points out, "wireless broadband represents a critical component of economic growth, job creation and global competitiveness because consumers are increasingly using wireless broadband services to assist them in their everyday lives."[21]

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17 *See* United Airlines Comments at 3.

18 *See id*. at 3-4.

19 NPRM, Statement of Chairman Julius Genachowski.

20 Jad Mouawad and Nick Bilton, "F.A.A. Nears New Rules on Devices," NEW YORK TIMES (Sept. 22, 2013) *available at* http://www.nytimes.com/2013/09/23/technology/faa-nears-new-rules-on-devices.html?pagewanted=1&nl=todaysheadlines&emc=edit_th_20130923.

21 CTIA – The Wireless Association Comments at 2 (quoting Service Rules for Advanced Wireless Services H Block – Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995- 2000 MHz Bands, WT Docket No. 12-357, *Report and Order*, FCC 13-88 at ¶ 2 (rel. June 27, 2013)).

For these reasons, the record now compels adoption by the Commission of its proposal to create this new service.

II. A Broad Swath Of Commenting Parties Agree That The Proposed Air-Ground Service Can Successfully Operate On A Secondary Licensed Basis At 14.0 - 14.5 GHz

Many parties and industry trade associations agree that the Commission can successfully establish a new terrestrial-based Air-Ground Mobile Broadband Service to aircraft in the 14.0 - 14.5 GHz band and that a secondary allocation is appropriate for the new service because then it may not cause harmful interference to primary-status services in the 14.0 - 14.5 GHz band, specifically Fixed Satellite Service ("FSS") applications, and must accept any interference it receives from those services.[22] Accordingly, Qualcomm agrees with Echostar, the NAB, and others who explain that the FCC "should adopt rules, licensing conditions and provide adequate notice to potential licensees and bidders that any ATG license provides for use solely on a secondary basis to FSS."[23]

As Qualcomm explained in its opening Comments, it supports the FCC's proposed regulations to protect the primary FSS users and the agency's proposed requirements that Air-Ground Mobile Broadband Service licensees coordinate their operations with Federal Fixed Service ("FS") and Mobile Service ("MS") licensees, the National Aeronautics and Space Administration ("NASA") Tracking and Data Relay Satellite System ("TDRSS") in the 14.0 -

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22 *See* NPRM at ¶¶ 2-8, 27. In this regard, Qualcomm agrees with the NAB's clarifications of the proposed rules § 22.1101 and § 22.1110(a) to make clear that the proposed Air-Ground Mobile Broadband service is a secondary allocation. *See* NAB Comments, Annotated Appendix of Proposed Rules. However, NAB's proposed new subsections § 22.1110(e) and § 22.1120(d) are not necessary and potentially confusing as they require the proposed service to protect all "existing operations in the 14.0 to 14.5 GHz band" and what is existing in the band will change over time.

23 *See* Echostar Comments at 2; *see, e.g.,* NAB Comments.

14.2 GHz band, and Radio Astronomy Service (RAS) users in the 14.47 - 14.50 GHz band.[24] Such coordination is consistent with and appropriate for a secondary allocation.

Qualcomm agrees with CORF that the only way for the Air-Ground Mobile Broadband Service to use the 14.47 - 14.5 GHz band for the aircraft-to-base-station link (*i.e.*, the Air-Ground service "uplink") is to coordinate with RAS observatories, and for the Air-Ground Mobile Broadband Service operator to avoid using this part of the band for aircraft-to-base-station uplink operations within a large enough area to protect RAS observatories during experimentation.[25] Away from these areas, Air-Ground Mobile Broadband operators should be allowed to use the 14.47 - 14.5 GHz band for both aircraft-to-base-station and for base-station-to-aircraft links, but Qualcomm agrees that the AMS operators must completely avoid using that portion of the band near impacted observatories based on 24 hour notice from RAS users.

III. <u>Many Commenters Support the Commission's Proposed Regulatory Framework</u>

Qualcomm is pleased that others support the FCC's proposal to add a secondary allocation to the 14.0 - 14.5 GHz band only for AMS and use for air-ground mobile broadband services exclusively.[26] As the FCC notes, the identified band is not appropriate for use by traditional terrestrial mobile services, for example, due to potential interference with incumbent users and poor propagation due to ground clutter.[27]

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24 *See* Qualcomm Comments at 12-14; NPRM at ¶¶ 28, 45; *and see* NPRM at ¶ 8, ¶ 15 and ¶ 29. *See also* National Research Council's Committee on Radio Frequencies ("CORF") Comments.

25 *See* CORF Comments at 5. Note that the Qualcomm Petition for Rulemaking refers to the base station to aircraft link as the downlink (*i.e.*, towards the user) and the aircraft to base station link as the uplink, which is the reverse of CORF's use of the terminology. In other words, CORF's use of the term "uplink" is the same as Qualcomm's use of the term "downlink."

26 *See, e.g.*, Echostar Comments at 8-9; NPRM at ¶ 50.

27 *See* NPRM at ¶¶ 49-51.

A. Air-Ground Mobile Broadband Service Operators Should Be Permitted To Choose Between Common Carrier And Non-Common Carrier Status

It is important that the FCC allow an Air-Ground Mobile Broadband Service licensee to specify its regulatory status similar to the provisions found in FCC Rule Section 27.10. As the Commission notes, a prospective licensee would benefit from the flexibility of being able to choose between providing common carrier and non-common carrier services, or some combination of the two, and that licensees in the 14.0 - 14.5 GHz band be required to identify their regulatory status on FCC Form 601 and provide notice to the FCC of any change in that status within 30 days of such a change.[28]

Also, while Qualcomm believes that the new Air-Ground service may be classified as CMRS,[29] the Commission should make clear in its final rules that a licensee will only be regulated as a CMRS provider if it offers a service that meets the definition of CMRS.[30]

In this regard, Qualcomm agrees with Gogo that Air-Ground Mobile Broadband Service licensees should be exempted from 911 and E911 regulations because contacting a traditional public safety answering point ("PSAP") 35,000 feet below a caller in an airplane moving at more than 500 miles per hour for emergency assistance is unlikely to be useful because the PSAP will be unable to reliably dispatch first responders to the airborne caller.[31] Moreover, in contrast to

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[28] *See* NPRM at ¶¶ 54-55. The FCC should not broadly impose common carrier non-discrimination provisions such as those proposed by United Airlines on all Air-Ground Mobile Broadband licensees, particularly where a licensee chooses to provide a non-common carrier service. Also, the proposed service is broadband Internet access, not telephone service.

[29] *See* Qualcomm Comments at 9, n.33.

[30] *See* NPRM ¶ 92 ("To the extent a licensee provides a CMRS, such service would be subject to the provisions of Part 20 of the Commission's rules along with the provisions in the rule part under which the license was issued.").

[31] *See* Gogo Comments at 13-15.

the flight crew, an airborne caller in an emergency situation is unlikely to know where or when the aircraft would land in order to reach ground-based emergency personnel.[32]

Also, the hearing aid compatibility requirements should not be applied to the Air-Ground Mobile Broadband Service because the proposed service only will enable a backhaul connection between base stations and aircraft and does not directly touch user devices.[33] End user devices, such as smartphones and tablets, will access the air-ground backhaul connection via Wi-Fi access points inside the aircraft cabin.

B. Multiple Parties Support The FCC's Proposed Licensing Rules And The Creation Of Two 250 MHz Licenses In The 14.0 - 14.5 GHz Band

Qualcomm believes that there could be significant cost-savings and operational efficiencies by having one provider operate a single network using the entire 500 MHz allocation. Such a terrestrial-based service provider would still need to compete with satellite-based providers. At the same time, there also could be competitive benefits from two terrestrial-based networks. Qualcomm believes that the market ultimately should decide whether one or two networks are viable.

Multiple parties support of the FCC's proposal to auction the spectrum in two 250 MHz blocks that could enable the deployment of two separate air-ground mobile broadband systems — one at 14.0 - 14.25 GHz and the other at 14.25 - 14.5 GHz .[34] Two separate systems can

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32 When the FCC first established its E911 rules, it exempted the existing Air-to-Ground service, explaining that airplane "passengers and crews do not rely on ground-based rescue operations. Instead [they] rely on other radio communications channels." *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Report and Order, Further Notice of Proposed Rulemaking, 11 FCC Rcd 18676, 18717 (1996).

33 *See* Hearing Industries Association Comments.

34 *See* Delta Airlines Comments at 3; ViaSat Comments at 7. *See* NPRM at ¶¶ 58-61. In contrast to ViaSat, however, Qualcomm supports the FCC proposal to allow a single entity to

operate in this spectrum and protect incumbent users of the band, including TDRSS at the lower end of the band and RAS users at the top end of the band, which operate in known geographic areas and known frequency bands that can be avoided by the Air-Ground Mobile Broadband Service, as necessary.

In light of the necessary coordination with incumbents in the 14.0 - 14.5 GHz band, particularly TDRSS at the lower end and Radio Astronomy ("RAS") at the upper end, it is not technically viable to have four 125 MHz licenses support four separate air-ground networks, as Gogo proposes, because there would not be sufficient capacity to reliably provide a nationwide broadband service.[35] Also, given that there are satellite-based providers, enabling up to two Air-Ground Mobile Broadband Service licenses will provide adequate competition while allowing a cost effective and high quality service to passengers on par with the level of service they receive on ground. Enabling more than two licenses in this band would increase the cost of the service, and decrease the quality of the service below what consumers need and expect.

Qualcomm believes that the Commission should hold an open auction in which the high bidder for each 250 MHz license should prevail, even if that means that one entity wins both licenses.[36] This auction framework would best enable the free market to decide the structure of this new business. In either case, licensing the service to two licensees or a single licensee will streamline the necessary coordination procedures with Federal FS and MS licensees, NASA

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hold both licenses for doing so could allow for the deployment of a more robust service with greater capacity. *See* ViaSat Comments at 7; NPRM at ¶ 69.

35 *See* Gogo Comments at 5-6.

36 Should the Commission nonetheless decide to auction four licenses of 125 MHz each, as Gogo recommends, *see* Gogo Comments at ii & 5, the FCC should allow a single entity to purchase all four licenses.

TDRSS and RAS users.[37] Having a limited number of Air-Ground Mobile Broadband Service licensees simplifies and thus improves interference remediation efforts in the unlikely event they are necessary. For all of these reasons, the Commission should auction two licenses in an open auction in which one bidder should be permitted to buy both.

C. Nationwide Licenses Will Enable The Rapid Deployment Of Air-Ground Services

As Delta Airlines, Echostar and Qualcomm explain, Air-Ground Mobile Broadband Service licenses should be issued on a nationwide basis, like the existing 800 MHz air-ground service is licensed.[38] Nationwide coverage is important because each Air-Ground Mobile Broadband Service licensee likely will want to provide service coast-to-coast service for both private and commercial aircraft that fly throughout the CONUS.[39]

The FCC should not define the spectrum into smaller geographic regions as some commenters have requested.[40] Defining smaller geographic service areas will only increase transaction costs, increase equipment costs and system design complexity for Air-Ground Mobile Broadband Service licensees who would then need to build nationwide license rights by securing multiple licenses that span the CONUS.[41]

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37 *See* Qualcomm Comments at 16; NPRM at ¶ 61.

38 *See* Delta Airlines Comments at 3; Echostar Comments at 12; Qualcomm Comments. The FCC need not, however, issue an FNPRM to develop a secondary service band manager as Echostar recommends. *See* Echostar Comments at 12.

39 *See* NPRM at ¶¶ 64-65.

40 *See* ViaSat Comments at 7.

41 *See* Qualcomm Comments at 17-18.

D. Qualcomm And Gogo Support The FCC's Proposed License Term And Renewal Criteria Regulations, And They Agree That A Five Year Build-out Rule Will Spur The Rapid Deployment Of Air-Ground Broadband Service

Qualcomm explained that a ten year license term is appropriate for the Air-Ground Mobile Broadband Service, which is the same license term that the agency has instituted for most other wireless services.[42] With regard to performance requirements, Gogo, like Qualcomm, supports the FCC's proposed substantial service definition and "safe harbor" to meet that standard.[43]

Both companies also ask the FCC to implement a five-year substantial service requirement because a ten-year deadline would unnecessarily keep this much needed service from the public and encourage spectrum speculators.[44] A five-year substantial service requirement, in contrast, will prevent spectrum warehousing and encourage both the timely and much-needed deployment of Air-Ground Mobile Broadband Service and investment in new technology, as Qualcomm explained in its opening comments.[45] Moreover, Gogo constructed its nationwide network in 26 months, and while Air-Ground Mobile Broadband Service base stations are more complex, deployment of several hundred base stations can be completed in three to four years post-auction.[46]

As noted above, should the Commission award two Air-Ground Mobile Broadband Service licenses, there should be no restriction on post-auction license assignments or transfers

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42 *See* Qualcomm Comments at 19-20; NPRM at ¶ 71.

43 *See* Qualcomm Comments at 20; Gogo Comments at 9 (proposing a clarification to the FCC's proposed rules to explain that service is only required to be provided above 10,000 feet and only to the extent that service requirements are consistent with coordination requirements with secondary users and RAS.

44 *See* Gogo Comments at ii.

45 *See* Qualcomm Comments at 19-20; NPRM at ¶ 74.

46 *See* Gogo Comments at 8-9.

of control (except for obtaining typically required FCC approvals) once a licensee meets the build-out requirements. Permitting post-auction license assignments or transfers of control without having to comply with the construction requirement encourages speculators.

IV. <u>The FCC's Proposed Operating Rules For The New Service Are Technically Sound</u>

A. <u>The Proposed Technical Rules Will Protect GSO Satellite Systems And Future NGSO Satellite Systems From Harmful Interference</u>

In its opening Comments, Qualcomm explained that the FCC should base the allowable ΔT/T or Rise over Thermal ("RoT") for GSO systems upon the technical parameters set out in Table 1 of the NPRM because it will ensure that the actual ΔT/T remains well below 1% during typical operation.[47] Qualcomm also demonstrated via calculations, based upon very conservative assumptions, that the limit for the average G/T over the CONUS is less than 4.5 dB, even with a high performing antenna and Low-Noise Amplifiers ("LNAs"). Qualcomm explained that in those cases where the G/T exceeds 4 dB/K, the satellite beam is very likely a regional beam that does not cover all of the CONUS evenly and does not see all the Air-Ground Mobile Broadband Service base stations or aircraft at the same G/T. Qualcomm asked the FCC to apply an average G/T of 4 dB for the emissions limits for CONUS beams into GEO arc, or suggested that the agency request from the satellite industry a G/T map of high performing satellites so that it may determine an appropriate value via an averaging of the G/T map.[48]

In their opening comments on the NPRM, the Satellite Industry Association ("SIA") and several of its member companies ask the FCC to use an average G/T (that is, the average FSS satellite receiver gain-to-noise temperature) of 6 dB/K for Ku-band satellite receivers.[49] SIA

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47 *See* Qualcomm Comments at 24.

48 *See id*. at 25-26.

49 *See* SIA Comments at 9-12; *see also* Boeing Comments at 6; Echostar Comments at 13.

claims that this level is the highest of the "average" G/Ts provided in an Appendix to SIA's Comments.[50] As Qualcomm stated in its opening Comments on the NPRM and restated above, very high performing CONUS beams would have an average G/T of approximately 4 dB. So, if G/T is higher than the average of 4 dB at some locations within the CONUS, then the G/T must be lower than 4 dB in some other locations over the CONUS to result in average of 4 dB.[51] And, since the Air-Ground Mobile Broadband Service base stations will be generally distributed in a uniform manner across the CONUS, the added interference received from a higher than average G/T location would be compensated for by the smaller amount of interference received from the lower than average G/T locations. In other words, average G/T should be used in the computations and not the high values of the G/T map.

SIA claims also that Qualcomm did not consider certain interference geometries that produce additional interference into GSO satellites.[52] SIA's claims are not accurate. As explained in the Petition for Rulemaking, Qualcomm considered satellites that are positioned at the far east and far west of the CONUS that would still have commercially viable beams over the CONUS. For example, a satellite at 140° East was considered. For a satellite at 40° West, parts of the CONUS that have a longitude of -120° and -125° are below the horizon with regard to the satellite. In addition, many areas of the CONUS at longitudes -105° and -110° for a GSO satellite at 40° West longitude have elevation angles well below 10°, as can be seen in Table A.3-2 in the Technical Annex to SIA's comments, that are not of commercial use. Indeed,

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50 *See* SIA Comments at 10.

51 *See* Qualcomm Comments at 24-26. Qualcomm notes also that only one of the assumed average G/T numbers in Appendix 1 of SIA's Comments is 6 dB/K. *See* SIA Comments at page 55 of 57.

52 *See* SIA Comments at 11, Technical Annex at 19-21; Echostar Comments at 13.

almost half of the CONUS has poor coverage from the 40° West satellite. Qualcomm provides below detailed calculations for the GSO satellite at 40° West longitude.[53]

Based on the aircraft antenna pattern in Qualcomm's Sept. 2, 2012, filing in RM-11640, the satellite located at 40° West longitude and ±5° an Air-Ground Mobile Broadband equipped aircraft, SIA concludes that interference from the aircraft would be 8 dB greater than what Qualcomm computed for the satellite at 140°E and that the allowable EIRP should be reduced by 8 dB.[54] Based on the calculations and discussion below, Qualcomm disagrees with SIA's interference estimate for the satellite at 40° West longitude and conclusion that the EIRP needs to be reduced by 8 dB.

The satellite at 40° West longitude has a wide azimuthal angle with respect to the low elevation angles of CONUS as shown in Table 1 below. Even if one uses the antenna pattern in Qualcomm's Sept. 2, 2012 filing, which had a very wide azimuthal beamwidth (when compared to antenna patterns that could be successfully implemented in a Air-Ground Mobile Broadband network), there is a large roll-off from peak in azimuth angles toward the 40° West longitude satellite, and the interference calculations must include this azimuthal antenna roll-off as well as the roll-off in elevation.

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53 The Qualcomm Petition analyzed the worst case scenarios. Analyzing the interference scenarios for every satellite scenario, as SIA suggests, would have been of limited value and lengthen unnecessarily the sizable Petition for Rulemaking and subsequent technical filings.

54 *See* SIA Comments, Technical Annex at 21.

	125	120	115	110	105	100	95	90	85	80	75	70
50.0	86.17	82.31	78.40	74.42	70.34	66.14	61.79					
47.5	86.31	82.59	78.82	74.98	71.03	66.94	62.70	58.26	53.60			38.06
45.0	86.46	82.89	79.27	75.57	71.75	67.79	63.66	59.32	54.74		44.72	39.23
42.5	86.62	83.21	79.74	76.19	72.51	68.69	64.68	60.45	55.96	51.16	46.03	40.52
40.0	86.78	83.53	80.23	76.83	73.31	69.64	65.77	61.66	57.27	52.55	47.45	
37.5		83.87	80.74	77.51	74.15	70.64	66.91	62.94	58.67	54.04	49.00	
35.0		84.22	81.26	78.21	75.03	71.68	68.12	64.30	60.16	55.64		
32.5			81.81	78.93	75.93	72.77	69.38	65.73	61.75	57.37		
30.0					76.88	73.90	70.70	67.24	63.43	59.21		
27.5						75.07	72.08			61.18		
25.0						76.29				63.27		

Table 1. Azimuthal angle from a line from center of each bin toward south relative to satellite at 40° W

The azimuthal roll-offs for different bins that were used in Qualcomm's interference calculations are computed by averaging the roll-offs over different aircraft locations in each hexagonal service area. At each aircraft location, the azimuthal angle between the line from boresight of the aircraft antenna to the nearest base station and the line from the aircraft to the satellite location is computed. The azimuthal angle for the specific aircraft location and the elevation angle for the bin are used to compute the combined roll-off due to azimuth and elevation roll-off for each location of the aircraft and averaged over all locations in each bin. Table 2 shows for each bin the combined average azimuthal and elevation antenna roll-off with respect to the satellite at 40° W.

	125	120	115	110	105	100	95	90	85	80	75	70
50.0			-15	-17	-19	-22	-22					
47.5			-15	-18	-20	-22	-23	-24	-25			-23
45.0			-16	-18	-21	-23	-24	-25	-25		-24	-23
42.5			-16	-19	-22	-23	-25	-25	-25	-24	-24	-23
40.0			-17	-20	-23	-24	-25	-26	-25	-24	-24	
37.5			-17	-20	-23	-25	-26	-26	-25	-24	-24	
35.0			-18	-21	-24	-25	-27	-26	-25	-24		
32.5			-18	-22	-24	-26	-27	-26	-25	-25		
30.0					-25	-26	-27	-26	-26	-25		
27.5						-27	-27			-25		
25.0						-27				-26		

Table 2. Combined average azimuthal and elevation angle aircraft antenna roll-off with respect to satellite at 40°W

Averaging the combined roll-offs over all bins results in a net roll-off of -21.4 dB. Table 3 below shows the RoT.

Number of planes	519.101124	Number in 77 bins out of 89[55]
Tx Power from Plane	3.0	dBW
Path Loss to GEO (~38k km))	-207.1	dB
Combined azimuthal and elevation roll-off over CONUS'	-21.4	dB
Polarization mismatch	0.0	dB
G/T of Satellite, GEO CONUS	2.0	dB/°K
1/BW, 2 MHz	-63.0	-dB Hz
1/Boltzman	228.6	-dB W/°K-Hz
I/N	-30.8	dB
RoT	0.082	%

Table 3. RoT for satellite at 40°W due to aircraft transmitters

It appears that SIA assumed that all aircraft across the CONUS are simultaneously positioned at +5° roll, which is not possible. It is more accurate to assume that the aircraft roll is uniformly distributed in ±5°. In this case, the impact of aircraft roll is accounted for by averaging the antenna gain over ±5° where half the aircraft will on average have a negative roll toward the geo-arc which means they will experience greater antenna roll-off toward the geo-arc. Qualcomm, in its computation of the effect of aircraft roll, purposely ignored the additional discrimination due to negative rolls to arrive at a conservative RoT level. Thus, an aircraft with positive roll uniformly distributed between 0° to 5°, based on the antenna pattern in Qualcomm's Sept. 2, 2012 filing, sees on average about 3 dB less discrimination toward the geo-arc. Since only half the aircraft experience a positive roll (while the other half experience a negative roll),

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55 Only 77 out of the 89 bins that cover the CONUS are visible from the satellite located at 40° West longitude, as shown in Table A.3-2 of the Technical Annex to SIA's Comments, so Qualcomm's analysis only considers base stations and aircraft within those bins.

the net loss of discrimination from the positively rolled aircraft is on average about 1.8 dB. This increases the RoT from 0.082%, without aircraft roll, as discussed above, to no more than 0.12%. This aircraft roll effect calculation is especially conservative for the satellite at 40°W because the aircraft antenna will be pointing towards a base station in the southward direction and away from the satellite at 40°W longitude. In this case, even when the aircraft rolls, there is little change to the emission towards the satellite at 40°W because of the azimuthal antenna roll-off covered above.

SIA also claims that Qualcomm did not properly project the worst case interference, such as where there is a high concentration of aircraft.[56] Qualcomm strongly disagrees. The baseline system that Qualcomm analyzed in the Petition for Rulemaking consisted of 150 base stations with four co-frequency beams at each site, where each site can serve a maximum of four aircraft simultaneously transmitting on the same swath of spectrum. Thus, Qualcomm's interference analysis accounted for the maximum possible aircraft in each site. If some base stations, such as those in low traffic areas, are serving less than four aircraft on a piece of spectrum, these sites will result in a lower RoT compared to the baseline (which has every base station operating four co-frequency beams at full power). In fact, non-uniformity of traffic will reduce RoT because the calculations in the Petition assumed that each site was serving the maximum number of aircraft on a given swath of spectrum.

This is why its interference analysis is conservative by a wide margin, as Qualcomm has explained repeatedly during this rulemaking. Qualcomm also explained that certain areas of the country with more aircraft traffic, such as the west and east coasts, may be accommodated via

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56 *See* SIA Comments at 11; Echostar Comments at 13.

cell splitting, which increases the number of sites in high traffic areas but reduces the per-site and per-aircraft EIRP and thus maintains the same (or lower) total emission into geo-arc.[57]

Based on the above discussion, the EIRP of the aircraft need not be lowered by 8 dB to account for the satellites at far locations such as 40°W longitude.[58] In any event, the proper approach to setting a rule for emissions into the geo-arc is exactly what the FCC proposed in the NPRM, which is to specify power spectral density ("PSD") into the geo-arc. Based on a G/T of 2 dB, the PSD into the geo-arc was specified to be -74.5 dBW/MHz per aircraft. If a G/T of 4 dB is adopted for interference calculations to account for the very high performing satellite beams discussed above, then the per-aircraft emission into the geo-arc would be reduced to -76.5 dBW/Hz.

Qualcomm favors specifying the PSD instead of EIRP for each aircraft because it provides flexibility in design by making the rule independent of antenna technology. If, for example, an Air-Ground Mobile Broadband Service operator can design an antenna with increased roll-off toward the geo-arc and actively point the beam as the aircraft rolls, the operator may be able to use a higher transmit EIRP so long as the PSD limit into the geo-arc is not exceeded.

Since its September 11, 2012 filing containing a prototype aircraft antenna pattern, Qualcomm has prototyped two more antennas and has measured their performance on a fuselage mockup to account for fuselage ground effects that has greatly improved performance than the

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57 *See* Qualcomm January 30, 2012 and March 29, 2012 filings in RM-11640.

58 *See* SIA Comments at 11-12.

earlier prototype. The fuselage mock-up that Qualcomm used is shown in Figure 1 below. The length and width of the flat portion of the cylinder are 4.57 m by 4 m.[59]

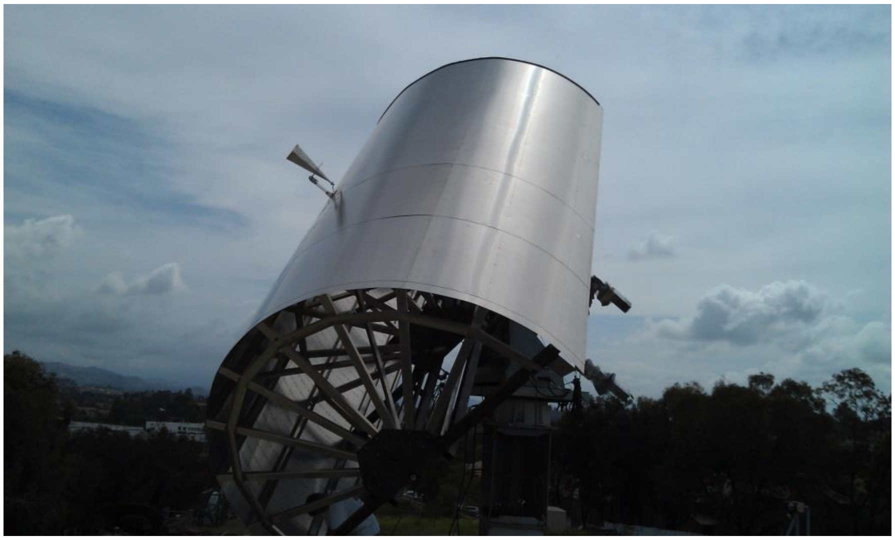

Figure 1. A cylinder mockup of the aircraft fuselage used for aircraft antenna measurements

Figures 2 and 3 below show aircraft antenna patterns as a function of elevation angle for one of the antenna designs. Figure 2 shows the elevation pattern for a beam that is pointing toward the front or back of the plane. Figure 3 shows the elevation pattern for a beam that points 60° away from the nose of the plane. In both cases, the elevation cut is made at the azimuth angle with the peak gain. The antenna roll-off shown in Figures 2 and 3 herein is much better than that of the antenna in the September 2012 filing.

59 Qualcomm is willing to provide the fuselage mock-up for testing of aircraft antennas to Air-Ground Mobile Broadband Service technology developers, system integrators and operators.

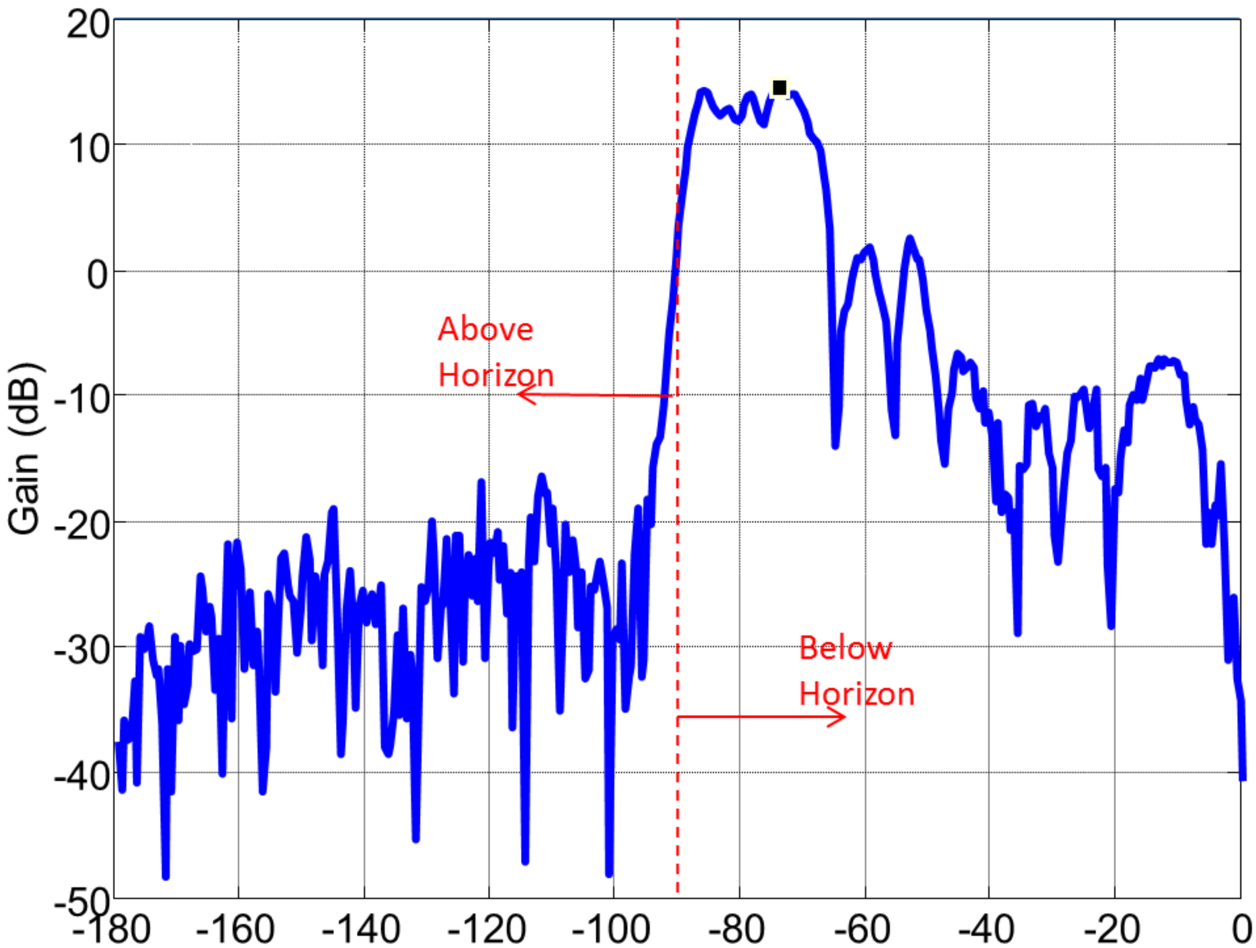

Figure 2. Aircraft antenna measurements in elevation angle for beam looking fore and aft as measured on the fuselage mockup

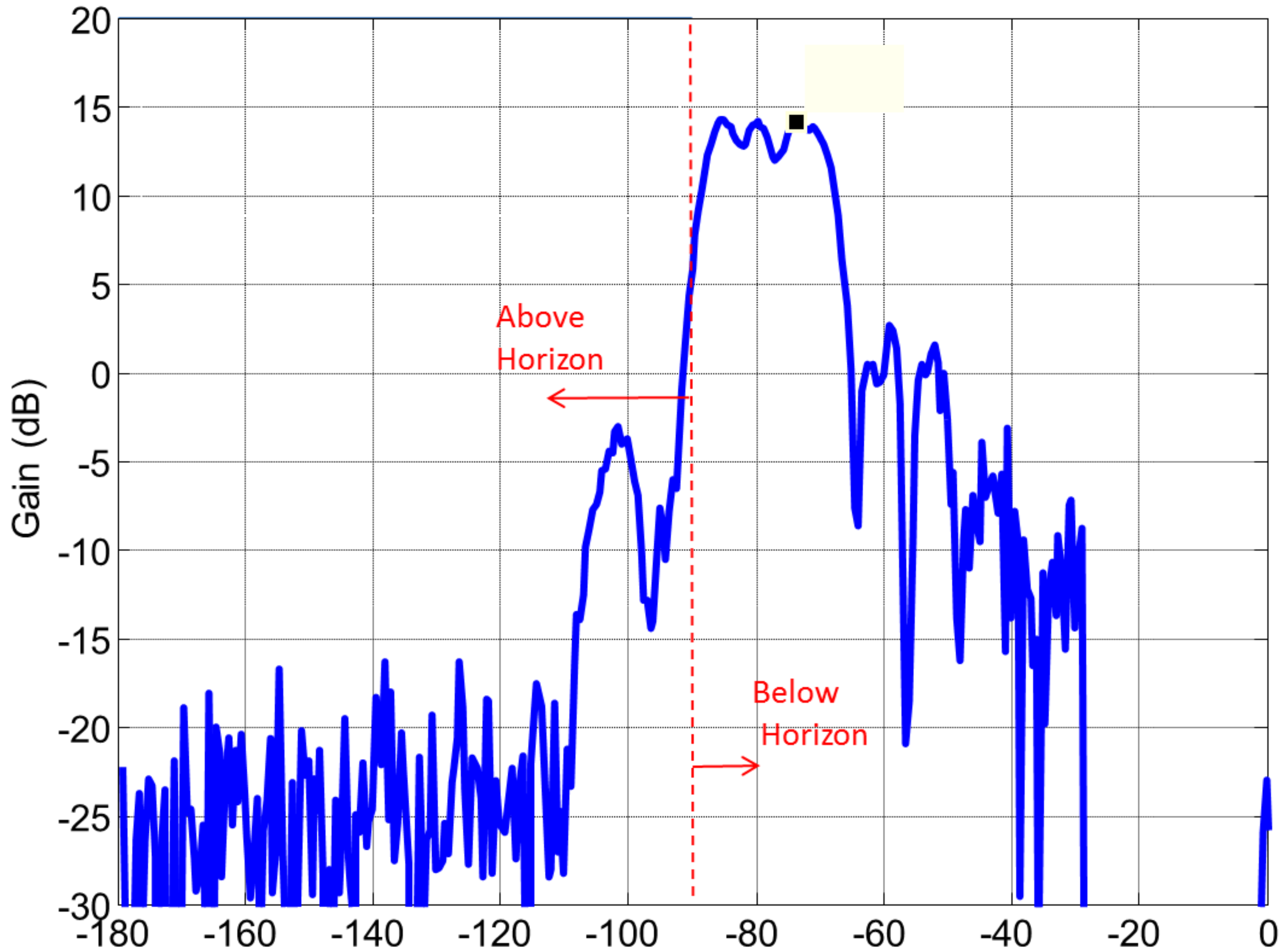

Figure 3. Aircraft antenna measurements in elevation angle for beam looking 60° away from aircraft nose as measured on the fuselage mockup

B. <u>The Southernmost Base Stations Need Not Be Treated Any Differently From The Other More Northerly Air-Ground Mobile Broadband Base Stations</u>

SIA asks the FCC to formally adopt Qualcomm's commitment to reduce the power of the base stations that operate near the southern border of the U.S.,[60] and SIA wants the FCC take steps to ensure effective monitoring and enforcement by instituting rules for the proposed power reduction and consider imposing recordkeeping requirements for the interference levels of the

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60 *See* SIA Comments at 18.

base stations.[61] SIA next raises concerns with regard to enforcing an allowable increased power level to compensate for rain fade by reducing the transmit level of other beams. Each one of these requests is addressed below.

In its opening Comments, Qualcomm explained that base stations located near the Mexico border need not power down to protect GSO satellite operations.[62] Qualcomm cited its Petition, which explained that the southernmost row of base stations would serve aircraft flying at azimuth angles greater than ± 60° from the station, and the EIRP of the serving beam will be reduced so as to meet the requirement of not interfering with GSO satellites, which is possible because the distance between the aircraft and base station is reduced in this configuration. The Air-Ground Mobile Broadband network operator must ensure that the emission into the geo-arc is maintained below the levels allowed under the FCC rules at all times. As will be explained below in response to Echostar's comments, the Air-Ground Mobile Broadband network operator must certify the base station antenna by measuring its three-dimensional antenna patterns by pointing the beam at the 5 azimuthal angles of true north, ±30°, and ±60° from true north, as described below, and demonstrate that the emission into angles toward geo-arc is below the allowable value for each azimuthal beam pointing angle. The power reduction mentioned in the Petition for the southernmost sites referred to the beams that may benefit from scanning at angles greater than ±60° from true north. If the Air-Ground Mobile Broadband operator decides to serve aircraft at azimuthal angles beyond ±60°, then the operator must add another scan angle beyond the ±60° to the tests to demonstrate that the emissions level into the geo-arc is maintained below the allowable limit for the beam scan larger than ±60°. The base station

61 *See* SIA Comments at 18.

62 *See* Qualcomm Comments at 26-27.

antenna test described below ensures that the emission limit is achieved at all azimuthal scan angles. Since at higher beam scan angles the aircraft is closer to the base station, then the EIRP toward the plane is lower compared to the beam pointing to true north. In certain cases, however, the data rate to aircraft very close to the southern border may need to be reduced, but it may be possible to maintain sufficient throughput to these planes by allocating greater transmission time to them.

SIA asks how the FCC can ensure that the antennas used by the Air-Ground Mobile Broadband system licensee will perform as well as the antenna Qualcomm used.[63] The antennas must be certified as mentioned above and discussed below in response to Echostar's comments.

Qualcomm described a means of verifying that no base station is interfering with a GSO satellite system in the Appendix to Qualcomm's July 31, 2012 filing in RM-11640 via making measurements on a specific satellite transponder. The Air-Ground Mobile Broadband operator should, as a condition of the license, similarly propose a technically sound means to verify that no interference will be caused when the system is installed and tested. The Air-Ground Mobile Broadband Service operator should provide measurements obtained at the aircraft and at the base stations on the operation of the system and provide a yearly report that the system is functioning properly. If at some point there is a complaint that the Air-Ground Mobile Broadband system may be causing interference, then the proposed interference testing scheme at the system installation time may be used to determine whether the Air-Ground Mobile Broadband system is causing harmful interference.

We agree with Echostar's general approach of using the regulations specified in its comments, specifically Rule Section 25.226 for VMES and Rule Section 25.132 for verification

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63 *See* SIA Comments at 19.

of antenna performance, as templates to specify equivalent rules for the Air-Ground Mobile Broadband Service.[64] Some details are different as explained below.

Qualcomm agrees that the per base station and per aircraft emission into geo-arc as well as the aggregate the emission limit from all base stations and aircraft into geo-arc should be specified. By way of example, the per aircraft or base station limit is -76.5 dB/Hz assuming 4 dB G/T for the GSO satellites, 600 simultaneous base station beams or aircraft on the same piece of frequency, and 0.5% RoT. The aggregate interference from all 600 beams or aircraft should be limited to -48.7 dBW/Hz. If the number of simultaneous beams/aircraft is different from 600 then the per beam/aircraft emission into geo-arc should be limited to -76.5+10*log10(600/N) when N is the number of simultaneous beams/aircraft on same piece of spectrum. The aggregate emission from all beams/aircraft remains the same regardless of number of beams, as Qualcomm has explained.

A maximum of 6 dB of power control should be allowed per aircraft or beam above the nominal value of -76.5 dBW/Hz. However, the operator shall provide information on the measures it will take to ensure that the aggregate emission into geo-arc is maintained below the allowable limit when some units transmit with as much as 6 dB more power.

With regard to the pointing of the aircraft antenna beam, the Air-Ground Mobile Broadband operator must ensure that regardless of the aircraft roll, the emission into geo-arc from the aircraft is below the allowed limit. The aircraft unit may, for instance, allow enough margin in its antenna elevation gain roll-off and/or use a gyroscope to detect roll and adjust its transmit power accordingly. The operator must demonstrate through documentation that its antenna and modem design ensure the specified emission into geo-arc is not exceeded during

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64 *See* Echostar Comments at 10-11.

aircraft rolls. The operator also must provide measurements of the proposed antenna in elevation at six azimuth cuts of 60° apart using a fuselage mockup, such as the one described in this filing. The fuselage mockup is a semi-cylinder with side dimensions of 4 and 4.57 meters. The antenna must be placed at the outer center of the cylinder. The proposed PA power into the aircraft antenna port then should be imposed onto the measured antenna pattern to ensure that the emission limit into the geo-arc is maintained.

The aircraft terminal must be capable of adjusting its transmit power within 100 milliseconds to ensure the emission limit into geo-arc is met under aircraft roll conditions. The operator must provide documentation of how it ensures that the total emission into geo-arc from all beams or aircraft is below the allowable limit.

The operator also should maintain sufficient statistical technical information on the individual aircraft transceiver and individual base stations and the overall system operation and file a detailed report, one year after license issuance, describing the aggregate EIRP-density levels resulting from the operation of the Air-Ground Mobile Broadband system. The Air-Ground Mobile Broadband operator should demonstrate that its aircraft terminals are capable of automatically ceasing transmissions upon loss of synchronization or within 5 seconds upon loss of reception of the base station downlink signal, whichever is less.

The operator should measure three dimensional antenna pattern of the base station antenna by pointing the beam peak at five azimuthal angles of zero degrees (*i.e.*, true north), and ±60°, ±30° from true north. The proposed PA power into the antenna port for beams at azimuthal angles of ±60°, ±30°, and true north shall be imposed onto the measured three dimensional antenna patterns to demonstrate that the emission limits into geo-arc are met.

Interference should be apportioned between multiple operators only if there are multiple operators using the same swath of spectrum in different areas across the CONUS (which

Qualcomm does not recommend as discussed above and in Qualcomm's opening comments).[65] In that case, each operator should only be allowed a portion of the RoT commensurate with its area of operation over CONUS. If the FCC divides the spectrum into two nationwide blocks of spectrum from 14.00 - 14.25 and 14.25 - 14.50 GHz, as Qualcomm and others recommend, as noted above, the interference on each piece of the spectrum is governed by the rules for a single operator as set out in the FCC's proposed rules governing emission limits into the geo-arc.

C. The FCC Should Use A 1% Aggregate ΔT/T For The Proposed Service Into GSO Satellite Operations For Purposes Of Developing Its Technical Rules

The Commission should define an aggregate ΔT/T of 1% for the Air-Ground Mobile Broadband Service into GSO satellite operations, recognizing that the proposed service will not come close to the 1% level given the transmit power requirements that it proposes to impose on the licensees.

Qualcomm supports the FCC's proposed regulation that the aggregate EIRP density into the GSO arc from all beams not exceed -46.7 dBW/Hz and that the EIRP density from a single beam into the GSO arc must be less than -74.5 dBW/Hz, based upon a total of 600 beams (*i.e.*, 150 base stations with four beams each). And, if the licensee increases the number of base stations from 150 to 250, EIRP density from a single beam into any point in the GSO arc must be proportionately reduced to -76.7 dBW/Hz.[66] Thus, Equation (1) in proposed Rule 22.1120(a) is appropriate as it lowers the emission from an airplane or base station into the geo-arc where the number of base stations is increased beyond 150. However, the aggregate EIRP density into any point in the geo arc needs to remain the same, *i.e.*, at -46.7 dBW/Hz. Only the per beam level needs to be reduced in order to keep the aggregate EIRP below -46.7 dBW/Hz — independent of

[65] *See* Echostar Comments at 11-12.

[66] *See* NPRM, App. B, Proposed Rule Section 22.1120(a).

the number of base station beams or aircraft.[67] Moreover, the foregoing power levels resulted in $\Delta T/T$ of 0.5%, which provides additional margin of interference protection for GSO satellite operations. Thus, there is no question that the FCC's proposed requirements will fully protect GSO FSS operations from harmful interference.

Also, because it is highly unlikely that all Air-Ground Mobile Broadband Service base stations will operate at the same levels simultaneously, the FCC should afford these secondary licensees the flexibility to distribute the power density of base stations according to traffic patterns and to optimize coordination with other, co-secondary, 14.0 - 14.5 GHz licensees.[68]

SIA and certain of its member companies request that the FCC limit the $\Delta T/T$ for the Air-Ground Mobile Broadband Service to 0.33%, so the level of interference from all existing and future non-primary users of the band does not exceed 1%.[69] But, setting the $\Delta T/T$ at that level is not necessary. As discussed in Qualcomm's March 28, 2012 filing in RM-11640, the assumptions and methodology used in the RoT calculations were conservative by at least 10 dB in arriving at 0.5% RoT from all base station and aircraft transmitters. Thus, there is adequate margin already in the RoT level for the baseline emission limit of -74.5 dBW/Hz for each base station beam and aircraft into the geo-arc, assuming an average satellite G/T of 2 dB.[70] The emission limit should be reduced by 2 dB if the FCC determines, for example, that an average satellite G/T of 4 dB should be used. Thus, there is no need to impose a 0.33% limit for the RoT.

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[67] Thus, Equation (2) in proposed Rule 22.1120(a) is not appropriate and should be removed from the proposed rule because the aggregate emission level should remain the same. As long as the aggregate emission level into the geo-arc remains below -46.7 dBW/Hz, then independent of the number of airplanes or base stations, the RoT will be below 0.5% based upon the assumptions in Table 1 of the NPRM.

[68] *See id.* at ¶ 112.

[69] *See* SIA Comments at 7-9; *see also* Boeing Comments at 5-6; Echostar Comments at 7.

[70] Indeed, Echostar agrees that such an approach is a feasible means of providing protection to FSS operations. *See* Echostar Comments at 8.

SIA also claims that if the U.S., Canada, and Mexico were each to introduce a secondary AMS in the 14.0 - 14.5 GHz, and each were to allow the AMS systems in their country to contribute the full one percent of $\Delta T/T$ into an FSS uplink, then a Ku-band satellite with a beam that spanned all three countries would suffer an aggregate impact into its receive beam in excess of one percent $\Delta T/T$ (especially when interference from existing secondary services are also taken into account). However, the interference from a secondary service in a different geographic area, such as Mexico or Canada, would have a small impact to a beam that covers the CONUS because the G/T of a beam covering the CONUS very likely rolls off by many decibels before it reaches these other geographic areas. In other words, secondary service in other areas should have a small interference impact on a beam that covers CONUS.

Echostar encourages the FCC to adopt a hard limit, specifically an aggregate power flux density ("PFD") for all Air-Ground Mobile Broadband services equal to -230 $dBW/m^2/Hz$ toward the GSO arc for it provides Air-Ground operators with a clear goal and thus increased certainty as to the level of protection they must provide, while enabling flexibility in design.[71] Such an approach also defines a useable interference threshold during operations or if an enforcement action is ever contemplated.[72] Qualcomm agrees with the calculation carried out in Annex A of EchoStar's filing which results in a power flux density of -210.1 $dBW/Hz/m^2$. However, it appears that when Echostar reiterated that result in the main body of its comments a typo was introduced, and resulted in stating -230 $dBW/Hz/m^2$.

71 *See* Echostar Comments at 8.

72 This approach also provides flexibility in design and addresses Gogo's concern that the FCC should not implicitly refer to Qualcomm's system design. *See* Gogo Comments at ii, 16-18.

D. **Aggregate And Individual Aircraft Antenna Power Limits Are Appropriate**

In its opening Comments, Qualcomm explained that the FCC rules should set an aggregate emissions level and an individual aircraft emission level into the geo-arc, and operators must design their system so that it meets both limits in the presence of aircraft roll.[73] Qualcomm agrees that the emission from all aircraft into geo-arc should be limited to -47 dBW/Hz, which corresponds to a $\Delta T/T$ of 0.5% and satellite G/T of 2 dB. A maximum emissions limit from an aircraft into the geo-arc should be defined once a G/T value is defined. The specification of total and single aircraft emissions into the geo-arc has the advantages of being technology independent and offering system operators design flexibility.

E. **The FCC Should Allow Increased Power To Compensate For Rain Fade**

The FCC should permit Air-Ground Mobile Broadband Service base stations to increase power up to 6 dB to compensate for rain fade when the EIRP density to the GSO arc from an individual base station is less than -68.5 dBW/Hz for an Air-Ground Mobile Broadband system with 150 base stations.[74] With regard to whether the additional power for beams affected by rain should come from powering down other beams or turning off some beams, Qualcomm proposes powering down other beams, as explained in its opening comments.[75]

Qualcomm showed that reducing the power of some beams to account for an increase in EIRP for other beams to compensate for rain fade, while maintaining the same total emission level into the geo arc, is a more bandwidth efficient approach than turning off beams entirely. Qualcomm thus respectfully requests that proposed Rule Section 22.1120(c) be modified to

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73 *See* Qualcomm Comments at 28-30 (Qualcomm explained that the Commission should define the per-plane emissions level the same way the agency proposes to define the base station EIRP; it should not limit the EIRP from each plane as the NPRM proposes).

74 *See* NPRM at ¶ 115.

75 *See* Qualcomm Comments at 30-31.

permit the use of power control so that total emission remains below -46.7 dBW/Hz when the power of some beams is increased to compensate for rain. As explained above, it is not necessary to reduce the number of beams used in order to maintain the same maximum transmitted power.

Boeing claims that rain fade produces scattering of RF signals that can affect the total amount of energy into the GSO arc via "re-direction of significant amount of energy via reflection from … ice crystals and snowflakes."[76] Qualcomm previously addressed the effect of reflection from rain and other perfect reflectors in the Appendix to Qualcomm's July 31, 2012 Reply Comments in RM-11640. Qualcomm demonstrated that there such reflections have a negligible impact on interference into the geo-arc.

F. The FCC Should Use A 6% Aggregate ΔT/T For NGSO Satellites Rather Than Set An Off-Axis EIRP Density In Directions Other Than Along The GSO Arc

In analyzing the impact of the proposed service upon potential NGSO systems, Qualcomm used an RoT of 6% because NGSO systems do not exist in the 14.0 - 14.5 GHz band today, and Qualcomm believes that such future systems can be designed to accept a 6% RoT level with negligible performance impact or cost.[77] Also, the NPRM asks whether the FCC should require an Air-Ground Mobile Broadband Service transmitter to turn off if an NGSO satellite is in the line of sight.[78] As Qualcomm explained, that may be required, but in only very limited circumstances as Qualcomm has explained previously and covers again below.

Qualcomm agrees with ViaSat (and others) that the proposed secondary use of the 14.0 - 14.5 GHz band for the Air-Ground Mobile Broadband Service must protect primary FSS

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76 Boeing Comments at 7.

77 *See* Petition at A-11 ("The values given for the target RoT … are thresholds for coordination given in Table 5.1 of Appendix 5 of the Radio Regulations.").

78 *See id.* at ¶ 116.

operations, including future NGSO FSS systems so as to not constrain development of such NGSO satellite systems.[79] ViaSat, however, claims that Qualcomm's analysis is not illustrative of the types of NGSO systems that are likely to be deployed in the Ku band and they do not reflect realistic operating parameters, and reference an architecture that is similar to the SkyBridge NGSO system that was previously licensed in the Ku band.

According to ViaSat and SIA, the SkyBridge system and Iridium and Globalstar NGSO systems, are characterized by orbits in which spacecraft would operate with hub antennas at elevation angles below 15°.[80] SIA and certain of its member companies also claim that Qualcomm analyzed one particular NGSO geometry and ignored other operational scenarios and variations in technical parameters.[81] SIA further claims that the RoT for NGSO operations should be set at 0.33% as it is for GSO operations.[82]

Given that any future NGSO system will have readily available for use the latest communication air interfaces and sophisticated error correction techniques, 6% RoT has a truly negligible cost impact (0.2 dB more EIRP) or performance impact upon NGSO system, as Qualcomm demonstrated in its opening Comments.[83] Also, the required additional EIRP for an NGSO system to overcome 1% RoT compared to overcoming 0.33% RoT is only 0.03 dB, which is a negligible and effectively non-measurable difference. Thus, requiring 0.33% or 1% limit rather than 6% RoT will impose an unnecessary additional complexity or loss of capacity

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79 *See* ViaSat Comments at 4.

80 *See* SIA Comments at 15, Technical Annex at 10-14; ViaSat Comments at 5 n.8; Echostar Comments at 14. The FCC need not issue an FNPRM to address these issues.

81 *See* SIA Comments at 13, 14; Echostar Comments at Annex B.

82 *See* SIA Comments at 13.

83 *See* Qualcomm Comments at 32.

on the Air-Ground Mobile Broadband Service without any measureable benefit for the NGSO system.

ViaSat also claims that NGSO systems in the Ku band serving the U.S. are more likely to operate at high inclination angles and lead to "direct in-line scenarios between" Air Ground Mobile Broadband Service base stations and NGSO operations.[84] ViaSat requests that Air-Ground Mobile Broadband operations be required to shut off to protect NGSO operations, which according to ViaSat, will provide "sufficient interference protection."[85] Citing the Qualcomm Petition at A-3, ViaSat suggests that the Air-Ground Mobile Broadband Service can use ephemeris data on the NGSO satellite locations to reduce transmit power when there is an in-line event.[86]

An Air-Ground Mobile Broadband Service base station beam should turn its power down (or completely off) if it is in line with an NGSO beam and causes an RoT to the NGSO satellite beam that is greater than 6%. The amount of RoT depends on the G/T and antenna pattern of the NGSO beam when it is in line with an Air-Ground Mobile Broadband Service base station beam. Based on the G/T and antenna pattern parameters provided by the NGSO operator, the Air-Ground Mobile Broadband Service operator should compute the RoT to the given NGSO system when the affecting beam is in line with the NGSO satellite. If the RoT to the NGSO beam will exceed 6%, then the Air-Ground Mobile Broadband Service beam should turn its power down enough (or completely off), to limit the RoT to 6% when it is in line to the NGSO satellite. Also, if the Air-Ground Mobile Broadband Service beam increases the RoT of an NGSO satellite to above 6% when it is in line with the satellite, and if powering down the beam does not reduce the

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84 *See* ViaSat Comments at 6.

85 *See id*. at 6.

86 *See id*. at 6-7.

RoT below the required threshold, the aircraft can be handed off to another base station that is not in line with the NGSO satellite.

Using different assumptions, SIA calculates the $\Delta T/T$ to be anywhere from 13.5 to 215%.[87] Qualcomm calculated the RoT to an NGSO satellite with beam G/T of -7 dB/K for a base station located at an elevation angle of 15° with respect to the satellite. The calculations assumed a sin(x)/x antenna pattern for the NGSO beam, that the peak of the NGSO beam is placed at an elevation angle of about 28° so that the edge of beam at 15° elevation rolls off by 2 dB from the peak. Moreover, due to the isoflux operation of the base station antenna, the base station beam was assumed to roll-off by 17 dB relative to its peak. The NGSO satellite was assumed to be at an altitude of 1000 km, which results in a distance of 2410 km from the base station at 15° elevation to the satellite. With these assumptions, the RoT from the beam at 15° to the satellite beam was computed to be about 0.8%, which was below the 6% that Qualcomm targeted in the Petition. However, as SIA points out, the RoT at a lower elevation angle of 1° to the satellite will be higher.

Next, we consider the RoT at elevation angles of 1, 2, 3, 5, 7 and 10 degrees. At these lower elevation angles, atmospheric losses must be considered. Moreover, the satellite antenna roll-off needs to be computed at different elevation angles. Table 4 below shows the atmospheric loss, satellite beam roll-off, base station beam roll-off and RoT for different elevation angles for the sample NGSO satellite described in the Petition. As shown in Table 4, the RoT is below 6% for all elevation angles when the base station is in line with the satellite. Thus, even at lower elevation angle of 1°, the RoT is below the 6% target RoT into NGSO proposed in the Petition.

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87 *See* SIA Comments at 15-16.

SIA's calculations do account for the atmospheric losses nor do they account for the additional NGSO antenna roll-off to a base station at a 1° elevation angle. Furthermore, Qualcomm agrees with general analysis methodology in Annex B of Echostar's filing on RoT to NGSO. However, Echostar's analysis did not include the base station antenna roll-off in elevation; due to the isoflux nature of the base station antenna, at 10° elevation the antenna rolls off by about -14.1 dB in elevation. Once the base station antenna roll-off of -14.1 dB at 10° elevation is included in Echostar's analysis, the RoT results will be close to Qualcomm's results presented below.

Base station elevation angle	1	2	3	5	7	10	15
Distance to satellite (km)	3599	3493	3390	3194	3012	2763	2410
Path loss	-186.68	-186.42	-186.16	-185.65	-185.14	-184.39	-183.2
Atmospheric loss	-3	-2.2	-1.7	-1.1	-0.8	-0.6	0
Satellite beam roll-off relative to peak	-4.64	-4.6	-4.52	-4.29	-3.96	-3.32	-2
Base station beam roll-off	0	-2.7	-5	-8.5	-11.2	-14.1	-17
RoT	4.60%	3.30%	2.40%	1.44%	1.00%	0.75%	0.80%

Table 4. RoT to NGSO satellite for base stations at different elevation angles

SIA claims that an NGSO satellite G/T performance level can reach 3 dB/K, which is 10 dB greater than Qualcomm's assumed value of -7 dB/K.[88] The sample NGSO system described in the Petition for Rulemaking assumed a satellite with 50 beams and G/T of -7 dB/K. Qualcomm chose these parameters because NGSO satellites with more beams and higher antenna gains would likely not be viable from cost perspective. In any case, if the NGSO satellite uses higher gain antennas, then its beams will be narrower and have high roll-offs

88 *See* SIA Comments at 15.

toward the base stations at low elevation angles, helping to keep the RoT into the satellite below the allowed threshold.

To illustrate this, consider an NGSO system with peak beam G/T of 3 dB/K consisting of 60 satellites, which can serve terminals at elevation angles of 20° or higher. Then, the NGSO antenna beam of a sin(x)/x type antenna placed at about 20° will roll-off by at least 16 dB from its peak at a base station at elevation angle of 1°, versus -4.64 dB for a beam with G/T of -7 dB in Table 4. Then, the 3 dB/K G/T beam falls off by at least an additional 11.36 dB relative to the Table 4 example. Thus, despite the additional 10 dB peak G/T the RoT at 1° elevation will, due to the additional 11.36 dB roll-off at 1°, be around 3.3% versus 4.6% of Table 4. Note that Case C of Table A.2-3 and A.3-3 in the Technical Annex to SIA's Comments assumes that an NGSO system with high G/T beams places its peak beam at low elevation angles of 1°. This is why SIA's results showed a very high RoT level. However, it is difficult to fathom an NGSO system which has beams with very high G/T of 3 dB and places the peak of the beams at elevation angles as low as 1°. This is a highly expensive and impractical case.

SIA also claims that Air-Ground Mobile Broadband Service-equipped aircraft will interfere with NGSO systems operating with elevations below 15°.[89] NGSO systems would handoff the terminal to the satellite that can best serve that terminal, *i.e.*, the satellite with highest elevation angle to that terminal. Even if the NGSO system has as few as 60 satellites, the lowest angle the satellite would serve a terminal before handing off it off to another satellite would be about 20°. Serving a terminal at lower elevation angles of say 15° would not be optimal. Nevertheless, based on the above calculations, for the sample NGSO system described in the Petition there is little interference to the NGSO satellite at elevation angle of 15°.

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89 *See* SIA Comments at 16.

If, as mentioned above, there is a future NGSO system where the satellite's G/T and antenna pattern such that the Air-Ground Mobile Broadband Service beams, when in line with the NGSO satellite, raise the RoT of the satellite beam above the allowed value, then it is incumbent upon the Air-Ground Mobile Broadband system to turn the beam's power down, or turn the beam off if necessary and handoff the aircraft to another base station.

Assuming a 0° elevation angle to the NGSO satellite and an aircraft banking at 5°, SIA provides calculations that demonstrate possible ΔT/T ranging from 0.06 to 0.94 percent for a single aircraft.[90] SIA claims that with each Air-Ground Mobile Broadband base stations providing up to four co-frequency beams, the aggregate interference to NGSO FSS satellites could be unmanageable. The RoT calculations carried out above assumed that the base station beam points directly at the NGSO satellite, *i.e*., no azimuthal base station antenna roll-off was assumed. Note that if one of the four beams happens to point directly or almost directly at the NGSO satellite then the other 3 co-frequency beams by definition will be many degrees away from in azimuth from the NGSO satellite and there will significant base station antenna roll-off in azimuth to the NGSO satellite. The reason the other 3 beams will be away from the satellite by many degrees is that the Air-Ground Mobile Broadband system itself has to protect each of its own beams from the other 3 co-frequency beams in each site otherwise the C/I on the beam will be low. Basically, one can think of the 4 beams as dividing the ±60 degree azimuthal area of the hexagonal cell site into 4 sectors and the 4 beams need to be spaced from each other adequately to avoid adjacent beam interference. Therefore, only one of the 4 beams needs to be studied in calculating the potential interference to an NGSO satellite.

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90 *See* SIA Comments at 17 & Technical Annex at 26.

G. Interference To Air-Ground Mobile Broadband Service Operations Will Be Managed Successfully

Qualcomm strongly believes that the proposed Air-Ground Mobile Broadband Service will operate successfully in the presence of potential interference from primary FSS users as its detailed technical filings in RM-11640 demonstrate. The FCC need not impose any "robustness requirements" upon Air-Ground Mobile Broadband Service licensees. The market for robust broadband service to aircraft via terrestrial-based and satellite-based systems will ensure that the Air-Ground Mobile Broadband Service is robust and reliable.[91]

Boeing claims that "operation of the proposed service within the constraints of secondary status could fall far short of user expectations with regard to data throughput rate, number of aircraft served simultaneously, and geographic operating area," and thus "compromise the commercial viability of the service."[92] Qualcomm strongly disagrees. As presented in the Petition for Rulemaking, the proposed Air-Ground Mobile Broadband system can provide at least 1 bps/Hz on each beam and with about 500 MHz of bandwidth and 4 co-frequency beams (*i.e.*, 4 reuses of the spectrum in each site), the capacity per cell site will be around 2 Gbps, which can be shared by the aircraft in that sector. With a minimum of 150 cell sites, the capacity across CONUS is at least 300 Gbps and scalable by cell splitting as Qualcomm has explained. This very high capacity service will provide, in a cost effective manner, services similar to what passengers enjoy at home. As FCC aptly recognizes, "Qualcomm has presented a substantial engineering analysis of the potential for harmful interference if we permit air-ground mobile broadband in the 14.0 - 14.5 GHz band, and of how that potential interference can be mitigated.[93]

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[91] *See* NPRM at ¶ 118.

[92] Boeing Comments at 8.

[93] NPRM at ¶ 25.

Moreover, the record establishes "that a system can be built in a way that can accept this interference from the primary satellite service and still provide acceptable service"[94] as further demonstrated by Qualcomm's opening comments and these reply comments on the NPRM.

H. The Air-Ground Mobile Broadband Service Will Successfully Share Spectrum With Irregular FSS Operations

SIA and some of its member companies claim that the 14.0 - 14.5 GHz band is used for tracking, telemetry and command and testing ("TT&C") during satellite transfer orbits and during launch and early orbit phase ("LEOP") operations and properly acknowledge that these operations are not protected as primary operations in the band.[95] According to these parties, TT&C use NGSO orbits and could suffer interference from Air-Ground Mobile Broadband Service operations.[96]

Qualcomm believes that it is possible to protect these FSS TT&C operations through techniques that are similar to how Qualcomm proposes to protect NGSO operations. It is Qualcomm's understanding that, during TT&C operations, the satellite is placed in a latitude angle as low as 25° (or even lower) with respect to the CONUS. Also, although the distance from the satellite to the Air-Ground Mobile Broadband base stations may be similar to the NGSO interference analysis case, the GSO satellite will be looking into the backlobe of the base stations, which is down by at least 37 dB as Qualcomm has previously explained. The PSD emission into the geo-arc based on an EIRP of 39.5 dBW/50 MHz and front to back lobe ratio of 37 dB is -74.5 dBW/Hz, as stated in the NPRM. Since the satellite is at low orbit only approximately 75 base stations will be visible from the satellite, *i.e.*, 300 beams. The power

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94 *Id*. at ¶ 27.

95 *See* SIA Comments at 22-23.

96 *See* Boeing Comments at 6-7.

averaged distance from these visible base stations to the satellite is about 1700 km. Moreover, during these irregular FSS operations the satellite is using a broad beam antenna with G/T as low as -20 dB/K. The I/N at the satellite receiver during TT&C operations is given by Table 5. Given that the NPRM proposed the same PSD emission from a single aircraft into the geo-arc as that from a single base station, *i.e.*, -74.5 dBW/Hz, the calculation in Table 5 applies to the RoT caused by the aircraft transmissions as well. Based upon the foregoing, there is little interference from Air-Ground Mobile Broadband system into the satellites during TT&C phase. The analysis in Table 5 is conservative for the same reasons previously explained by Qualcomm.

Power averaged distance from base stations to TT&C satellite	1700	km
Number of beams	300	
Power spectral density emission into geo-arc	-74.5	dBW/Hz
Path loss to satellite at 1700 km	-180.1	dB
Polarization mismatch	-3.0	dB
Average atmospheric loss	-0.6	dB
G/T of satellite receiver during TT&C	-20.0	dB/K
1/Boltzman	228.6	-dB W/K-Hz
I/N	-24.9	dB
RoT	0.33	%

Table 5. I/N calculation at the satellite receiver during TT&C operations

SIA claims that new electric propulsion satellites will require as long as six months to reach GSO orbit, which means extended exposure to interference from the proposed service.[97] SIA asks the FCC to make the proposed Air-Ground Mobile Broadband Service subordinate to these irregular FSS operations. That would not be appropriate given that these operations do not

97 *See* SIA Comments at 23.

have primary status in the band. In any event, based on the calculation shown in Table 5 above, there is negligible interference to GSO satellites during their TT&C procedures.[98]

[98] Qualcomm's analysis is based on parameters that it understands apply to TT&C operations. The company recognizes that it may need to revise the analysis if it is shown that the parameters do not accurately represent actual operations and that the Air-Ground Mobile Broadband Service operator may need to coordinate with TT&C operations.

CONCLUSION

Qualcomm respectfully requests that the FCC promptly issue a Report and Order authorizing the service proposed in the Air-Ground Mobile Broadband NPRM in accordance with Qualcomm's comments and the foregoing reply comments. Qualcomm looks forward to enabling multi-gigabit-per-second air-ground broadband communications services that are needed to support the exploding usage of mobile broadband devices, applications and services on in-flight aircraft well into the future.

Respectfully submitted,

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